

Weather On Target

Paul M. Tag
NRL Monterey
7 Grace Hopper Avenue
Monterey, CA 93943-5502
(831) 656-4885, (831) 656-4769 (FAX)
tag@nrlmry.navy.mil
N0001498WX400008 (BE-35-2-20)
<http://www.nrlmry.navy.mil>

LONG-TERM GOALS

Because Navy and Marine Corps personnel operate over large, often remote, regions and undergo frequent rotational assignments, they need well-developed tools that can be used to supplement basic meteorological skills with local information and knowledge for specific regions. Our long-term goal is to develop enhanced automated local analysis and prediction tools to provide an essential ingredient to tactical success in Strike, Surveillance, and Littoral Warfare Joint Mission Areas.

OBJECTIVES

The objective is two-fold: to develop automated analysis and forecast tools to improve on-scene weather forecaster knowledge of localized weather conditions, and to utilize conventional and remotely-sensed data to provide nowcasts and forecasts of key meteorological parameters that are needed by the warfighter. While today's forecasters rely heavily on numerical analyses and forecast model guidance, and the skill of those models is constantly improving, the models cannot at this time satisfy all of the warfighter's requirements. In some cases, the warfighters may need meteorological parameters, such as visibility, that are not produced directly by existing operational models. In other situations, the model analysis or forecast may be improved by applying specific, localized knowledge of typical atmospheric patterns and behavior to the interpretation of observations and/or model products. Improved nowcasts and forecasts of parameters such as wind, visibility, and cloud-base height in the battleground arena will yield payoffs in terms of increased mission success and in cost savings from fewer weather-related aborted missions.

APPROACH

Our approach is to attack the problem of enhancing local analysis and forecast skill from several avenues, since the optimum technique may depend on the particular weather parameter of interest. One obvious way to make up for numerical model deficiencies is to look for ways to improve the model. There are many ongoing efforts within NRL that are working on that approach, and the new high-resolution nonhydrostatic models hold great promise for being able to analyze and predict cloud base height, for example, which previous models could not. But even these highly sophisticated models, such as the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS), do not predict visibility. However, if we integrate an aerosol process model into a three-dimensional meteorological mesoscale model such as COAMPS, we can provide a more accurate description and prediction of horizontal variations of visibility and EO wave transmission. Initially, we will conduct sensitivity studies

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to better understand the characteristics of the aerosol model and the mechanics of coupling to COAMPS, before fully integrating the aerosol model directly into COAMPS. Finally, we will evaluate the coupled system by comparing the model results with observational data collected in field experiments. As part of these tests, we will apply the mesoscale/aerosol model to studies of dust storms in the Persian Gulf area. From these studies, we first hope to reproduce the observed characteristics of the specific synoptic conditions leading to the dust storm, which can then be generalized into a set of forecasting rules (or expert system) to further aid local forecasters concerned with such events.

Expert systems can encapsulate traditional man-in-the-loop weather forecasting expertise and experience into software form. This type of technology is particularly applicable in areas subject to very localized weather events where the numerical models may not have enough data, resolution, or skill to capture the conditions leading to the events. MEDEX (see Progress, below) is an example of an expert system that also employs fuzzy logic to yield outputs that are insensitive to small changes in input.

Another AI technology having great potential for meteorology is computer vision. As an example, while numerical models provide fairly accurate estimates of tropical cyclone tracks, they are not very skillful when it comes to analyzing and forecasting tropical cyclone intensity. As a result, this task is still conducted manually by typhoon duty officers who are often lacking all the information they need to make an accurate assessment. We are using computer vision (pattern recognition) to develop an automated classifier for tropical cyclone intensity. In this effort, we will leverage a database that was developed for other remote sensing projects at NRL; this database relates Special Sensor Microwave/Imager (SSM/I) imagery to the human classification (best track) of tropical cyclone strength. Special vision features will be developed from the SSM/I data to isolate particular tropical cyclone characteristics that discriminate storms of different intensities. The skill of the automated classifier will be evaluated.

WORK COMPLETED

The fuzzy expert system MEDEX was completed in FY97 (see Kuciauskas et al., 1998) and provides forecasting assistance to predict the gale-force onset and cessation for seven major wind events in the Mediterranean region: levante, westerly, mistral, bora (Adriatic), bora (Aegean), etesian, and sirocco, with separate rule bases for the summer and winter. FY98's work involved the use of the MEDEX developmental database to assess gale-force wind events at specific Mediterranean ports.

Computer vision techniques are being used to develop an automated classifier for tropical cyclone (TC) intensity using SSM/I imagery (Bankert and Tag, 1998). Special vision features have been developed to isolate TC characteristics associated with storm intensity; optimal features are selected from a larger set using feature selection techniques.

A passive scalar transport module has been imbedded inside COAMPS. In this tightly coupled implementation, the predicted and diagnosed meteorological fields are used every timestep eliminating potential uncertainties that exist in loose coupling. The coupled model has been applied to a study of a dust storm in Iran and over the Gulf of Oman and found to reproduce the observed characteristics of the dust storm. The coupled model has also been used for predictions of the potential transport of gasses from sites in Southwest Asia.

RESULTS

To assess whether forecast rules could be developed for specific Mediterranean ports, the MEDEX developmental database (consisting of MEDEX input values) was first combined with observational winds for 13 different ports for the two-year period of the database. Using this combined database, knowledge discovery techniques were then used to formulate forecast rules for eight ports for which the observational station was considered representative of the port itself. The rules for seven of these ports are sufficiently robust that they will be incorporated into MEDEX in FY99.

Since last year the tropical cyclone (TC) database used to develop the automated intensity algorithm has been increased from 389 to 881 in number. In addition, new computer vision features representing storm structure have been added. Using a selected subset (using feature selection) from the 125 total features, classifier evaluations have RMS and average absolute (AA) errors of less than 15 and 11 knots, respectively, using leave-one-out (LOO) cross-validation testing. A new two-step technique, in which cyclone intensities are first classified into general groupings (e.g., tropical depression, tropical storm, weak hurricane, etc.) and then further distinguished using that classification as an input feature, has reduced LOO errors to less than 14 and 10 knots, respectively, for RMS and AA errors.

Numerical simulations of the dynamics in southern Iran using COAMPS have revealed a strong barrier jet and downslope wind event in the vicinity of a dry lake bed, a likely source of dust (Liu et al. 1998). An analytical study has identified the necessary environmental conditions for the formation and persistence of barrier jets over sloping mesoscale valleys (Xu et al. 1998). These include the profile of the cross-valley terrain, free tropospheric wind speed and direction, valley slope, and slope of the top of the cold-air pool. The COAMPS results are in agreement with the analytical model, indicating that the study has been successful in explaining the jet and that COAMPS has skill in predicting the jet.

In a demonstration, the coupled aerosol-COAMPS model is run every day in a research/operational mode for the region of Southwest Asia. Four hypothetical continuous sources are located at Jerusalem, Baghdad, Tehran, and Riyadh. The figure shows a sample of the 12-hour forecast of concentration at 10 meters AGL valid at 1200 UTC July 12, 1998. The plume shapes vary from site to site and from day to day and are determined by the synoptic and mesoscale circulations and by local land, sea, mountain and valley breezes.

IMPACT/APPLICATIONS

MEDEX, including the new forecast rules for specific ports, will provide a forecasting tool for the regional forecast center (NEMOC) in Rota, Spain. This expert system, including its tutorial, help, and explanation facilities, will be particularly useful as a training aid for newly-assigned forecasters. The quasi-final version was demo'd to NEMOC this past spring and enthusiastically received. Our TC intensity algorithm is intended for use at the Joint Typhoon Warning Center as a first-look aid to assist forecasters in properly assigning an intensity to satellite-observed TCs.

The Iranian dust storm case study, when combined with others, will allow development of dust storm forecasting rules built upon an existing knowledge of Shamal forecasting. This approach would have been invaluable to forecasters during the Iranian hostage rescue mission of 1980 (and any future Iranian

missions), since reports indicate that the fateful dust storm occurred in the same location and under similar post-Shamal conditions as the SHAREM 110A event.

TRANSITIONS

The MEDEX port rules will be transitioned to 6.4 at the end of FY98. The TC intensity aid is planned for transition to 6.4 at the end of FY99. The aerosol modeling effort will continue as part of a new FY99 6.2 project within the NRL base program.

RELATED PROJECTS

The expert system and computer vision work are coordinated with a parallel effort being conducted with 602435N funding (ONR direct funding). In particular, in FY98, the ONR component focused on a new technology called Knowledge Discovery from Databases (KDD), looking for biases in the COAMPS predictions of cloud base height, a key parameter affecting many tactical operations. The results and experiences from this ONR-funded component formed the basis for a four-year New Start (NRL 6.2 base funding) scheduled for an FY99 beginning. The work performed under both of these 6.2 efforts is further supported by PE 603207N (6.4) for implementation into an operational product (SPAWAR PMW-185). Other related research (also under PE 603207), funded through Point Mugu, is supporting the development of an expert system (ExperDuct) for the prediction of atmospheric electromagnetic ducting (SPAWAR PMW-185).

The aerosol modeling work is coordinated with an ONR-sponsored "Coastal Aerosol Characterization" project (PE 602435N) in which the data assimilation capability for aerosols will be developed. Other activities related to aerosol modeling work are (1) the 6.1 RO (Coastal Aerosol Processes), (2) two 6.4 efforts in EOTDA evaluation and aerosol measurement (PE 603207N), and (3) investigations of gas transport for the Office of the Special Assistant for Gulf War Illnesses (OSAGWI).

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IN-HOUSE/OUT-OF-HOUSE RATIOS

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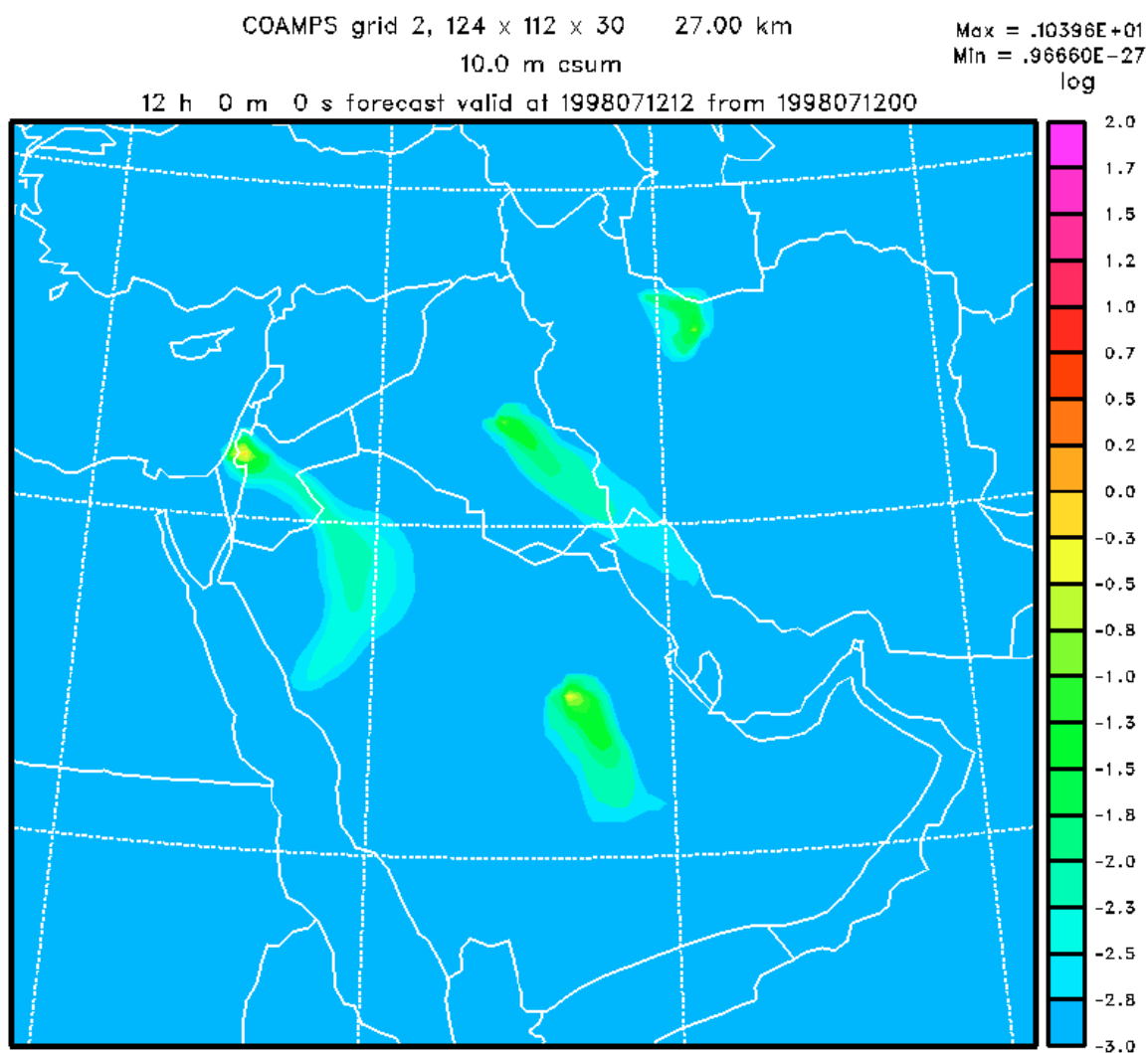


Figure 1. Real-Time Predictions of passive scalar transport. The pattern shows the 12-hour forecast of dosage (arbitrary units, logarithmic scale) valid at 1200 UTC July 12, 1998. The emission at the four sites is continuous in time. The 12-hour concentration field is used as the first guess for the subsequent aerosol-COAMPS run.